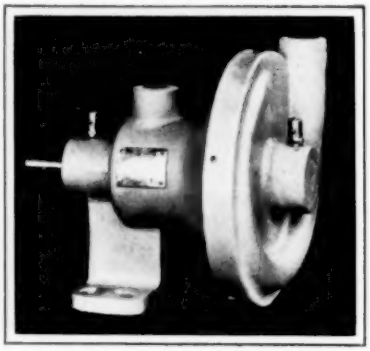
JOURNAL

DECEMBER, 1932

Wm J McKEEN



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A. S. T. E. Journal

Published by the American Society of Tool Engineers

8316 Woodward Avenue

Detroit, Michigan

J. A. Siegel, President

W. H. Smila, First Vice-President

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VOL. I. DECEMBER , 1932 No. 8

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Owing to the nature of the American Society of Tool Engineers organization, it cannot be responsible for statements appearing in the Journal either as advertisements or in papers presented at its meetings or the discussions of such papers printed herein.

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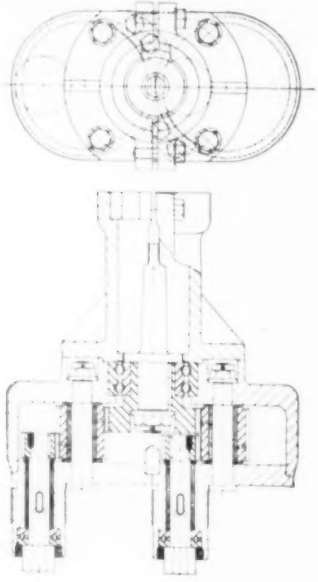

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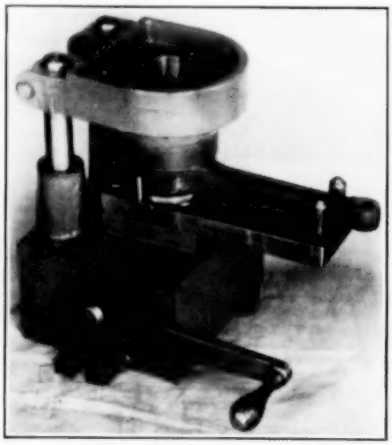

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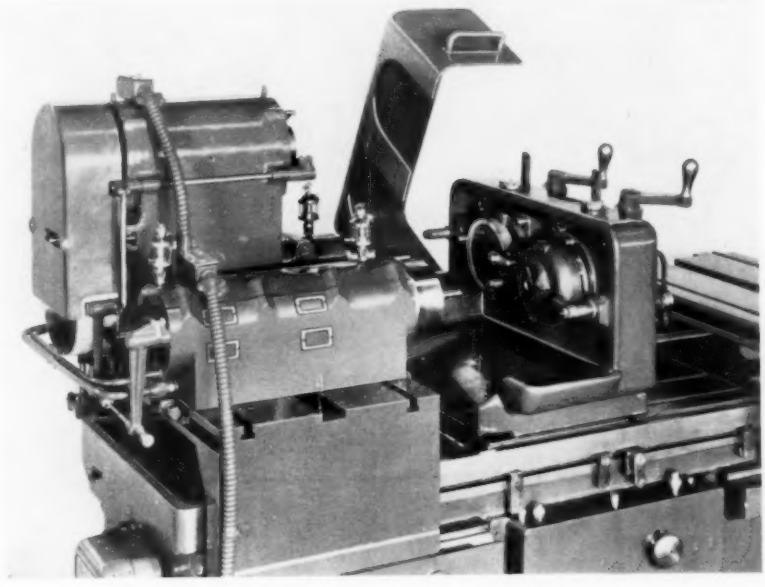

CLOSE-UP view of machine for boring two different types of bakelite timing gears and motor end frames simultaneously.

At the front of the machine is a direct connected, balanced motor driven boring unit for boring the bronze bushings in motor end frames.

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CHAPTERS COMMITTEE REPORT

Some inquiries have been received from different sections relative to Chapters of the American Society of Tool Engineers, and the Chapters Committee will have a complete report covering the details of organizing Chapters of this Society ready for publication in the January issue of the Journal.

In a general way, a new Chapter may be organized as follows. All organizers of the Chapters must be members of the Society. When any section or city has a sufficient number of members they may apply for permission to organize a section for the purpose of conducting meetings in their own locality. A portion of the dues of their members will be returned to them when permission is granted and their section organization completed. These funds will be to help defray the expense of their Chapter. All subjects or technical papers given at section meetings will be published in the Society Journal. The section will operate according to the Constitution and By-Laws of the American Society of Tool Engineers. The object of course, is to further the science of tool engineering among tool engineers; also to aid them in their work and bring about a better understanding of the nature and value of tool engineering.

Members in industrial cities other than Detroit can approach other tool engineers in their respective cities for the purpose of discussing the possibility and advisability of having a Chapter in that city. They can obtain information from Mr. Sargent, Secretary of the Society, relative to the number of members already enrolled from their city. The first requisite for organizing a Chapter is sufficient members. Next month the Journal will publish details to be followed, and all aid and information possible will be furnished from the Secretary's office or the Chapters Committee.

DUES REDUCED FOR YEAR

At the November 17 meeting of the Board of Directors of the American Society of Tool Engineers, it was voted to reduce the Society Senior Members' dues from $5.00 to $3.00 for the year 1933, making the schedule as follows:

Article IV—Fees and annual dues.

Section I—Initiation or entrance fee
- a—Senior Members, $5.00
- b—Junior Members, $5.00

Section II—Annual dues for 1933
- a—Senior Members, $3.00
- b—Junior Members, $2.00

This schedule becomes effective January 1, 1933, and does not effect the present offer during the membership race of $3.00 entrance fee until the first of the year.

This action by the Board of Directors was taken after much discussion of the present industrial condition, and majority opinion was to the effect that the officials of the Society would have to continue to operate the business of the Society along present economical lines until industrial volume increased substantially. At the present time no salaries are paid to any officials, directors, or committee members.

THE TOOL ENGINEER'S DREAM OF A

MERRY CHRISTMAS

Next meeting:

Thursday, Dec. 8, 1932.

Detroit Leland Hotel,

Colonnade Room,

Eight o'clock.

Speaker:

J. Musser Miller,

B. S. in Chemical Engineering, University of Michigan, — 1921.

Standard Oil Company, (Indiana).

Technical Department.

Subject: The Story of Gasoline.

At the December meeting, December 8, 1932, Mr. J. Musser Miller of the Technical Department of the Standard Oil Company of Indiana, will present the "Story of Gasoline," giving the origin, history, and development of one of the most important resources of the nation. The production of gasoline has developed into one of the major industries of this country, and millions of dollars are invested in the business of producing, refining, and marketing this product. While we as tool engineers may not be directly connected with this industry, we are interested to learn something of the things upon which our business depends. Surely, Tool Engineering as applied to automobiles would not be very far advanced if we did not have gasoline.

ANNOUNCEMENT

Mr. Earl J. Ruggles, Chairman of the Meetings Committee, announces that the January meeting will be a dinner meeting similar to the November meeting. Price, place, and time will be announced in the January issue of the Journal, and Mr. Ruggles promises a very interesting meeting.

POSITION WANTED

Designer, 42 years of age, unencumbered, eight years practical shop exeprience; have been employed in the capacity of shop foreman, studied mechanical engineering in the evening, for past 16 years; have gained a broad varied experience designing automatic and special machinery, for labor saving and production, tools, jigs, fixtures, punches, and dies for interchangeable parts; have been employed in various capacities; am quick, neat, accurate, can produce results economically; any location or capacity, salary commensurate to present conditions.

ELMER KOLP,
2541 W. Oxford Street,
Philadelphia, Pennsylvania.

ANNOUNCEMENT

Mr. John H. Spehr, formerly with the Strelinger Company, is now associated with the Gullberg Sales and Manufacturing Company, Inc., manufacturers of standard and special die sets and a complete line of die maker's supplies.

Truth will always be of few men, and must therefore quietly and modestly wait for the few whose unusual mode of thought may find it enjoyable.

—Arthur Schopenhauer.

EDITORIAL PAGE

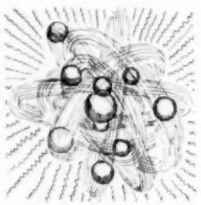
ALPHA AND OMEGA

The modern scientific conception is that the first spark of life on earth came into existence in the primordial seas when mother earth was several hundred million years younger than she is today.

We are now taught that this first cell of life, the "manward impulse," struggled upward through fish, reptile, and beast, and survived through millions of years of never-ending battle on land and sea.

A stormy, and yet orderly, churning of the elements must have created a vacuum which life alone could fill, else this spark of life, so tiny as to be invisible to the naked eye, could not so amazingly have overcome the eons of vicissitudes encountered in its climb from the steaming, slimy sea shores to spread itself and its descendants over the face of the earth to culminuate in the being known to us as *man*.

Somewhere along the trail from antiquity he discarded the air-bladder, fins, and gills, of fishes, and replaced them with lungs and limbs of locomotion and acquisition. As one of many relics picked up along the tedious journey he has kept the universally-jointed neck of the snake to properly support his cranium, in which resides the one acquisition which differentiates him from the remainder of his fellow animals—the member which we think is the seat of the most powerful force on earth—his brain. Man thus became a thinking, reasoning animal.



Electrons moving about proton (center), and radiating photons.

An atom in a tiny grain of sand is relatively much larger than is man in proportion to the vastness of the small portion of the universe now known to him. Yet, this thinking atom, with the audacity of lightning, feels himself to be the pivot around which revolves the "eternal purposes of the universe." He finds himself of supreme importance and interest—to himself—as he ponders over whence he came, why he came, and whither he is going. His ego is quickened by the thought that he has overcome all his natural earthly adversaries which in legion infested his path. He has conquered even his arch enemy, Death, by finding a God to lift hi mover the river Styx. His foes are scattered like leaves by a hurricane—all except one. That one is an object of his own creation. In terror he fears that it threatens to be his utter undoing. He calls it "civilization."

As man began to emerge from the jungle of kindred beasts and assumed the Simian characteristics now identifying him, he began utilizing weapons, fire, and tools in the preparation of his habitat, food, and clothing. Today his very existence depends upon literally thousands of applications of laws and principles which he has discovered. The use of each of these laws was a luxury when first he employed it for his comfort and convenience. He has always been master of his first act and slave to the habit developed by the repeated act. It has pleased him to build himself a pinnacle on which to rest and view the wonders of nature—and himself. He finds, however, that he cannot rest, for he discovers that he has imperfectly understood the laws which he has diverted from their natural paths, and that these laws now enslave him. The system of natural laws is vast, complex, and terrifying.

The masses cannot keep abreast of the very few who go beyond the borderline of average intelligence. The few who most perfectly understand and employ the laws become the masters of the masses.

The masses begin to suspect today what the explorers have known for years, namely, that a knowledge of the intermolecular action and interaction of protons, electrons, and photons would benefit man more than a historical knowledge of man-made laws and his "noble experiments," therewith. Radio-telegraphy, the photo-electric cell, and the study of radium emanations incite the mind to ponder whether, as man goes through this world being constantly bombarded and "shell shocked" by rays and emanations from unknown sources, his actions may not have been "remote-controlled" by photons conveying ideas from men whom he may never have seen and whom he may never see.

The world war and its cataclysmic aftermath of unbridled emotions and consequent world-wide human misery strikingly depict the explosive violence and destructiveness of the wrong application of fundamental physical and psychical laws. Man's noblest institutions tottered. Fear was everywhere in the land.

The humility which precedes every upward push of man now bows the heads of all who think.

The foundation is thus laid for ten years of the most spectacular progress in truth finding man on earth has ever known.

Perhaps the above pictures why the ASTE has grown so rapidly. Perhaps men everywhere really *do* want to learn. The ASTE was organized to diffuse the knowledge of Tool Engineering among its members.

MEMBERSHIP DRIVE

Below are given the standings of the ten teams now in the heat of the membership race. Mr. F. L. Hoffman's team is maintaining its lead, and it looks as though the dinner, at the expense of the other teams, is going to team No. 2. But the race has still one more month to run, and anything may happen in that time. So don't give up, you all still have a chance.

1. C. B. SMITH, *Captain*
   E. M. BEYMA
   DWILLARD J. DAVIS
   ROBT. W. FRYE
   ED. SHUBACK

2. F. L. HOFFMAN, *Captain*
   WALTER F. WAGNER
   KENNETH C. SNELL
   WM. C. MAIER
   O. B. JONES

3. WM. (BILL) GRAY, *Captain*
   JOE DILLON
   B. BUSWINKA
   T. POUTTU
   J. GIERN

4. E. C. MacKenzie, *Captain*
   C. THIEDE
   JOS. P. MILLER
   KARL W. LEGG
   HERBERT B. NORQUIST

5. GEO. E. LEGGATT, *Captain*
   LEE DIAMOND
   H. C. BEHM
   W. L. NEWTON
   CHARLES R. STAUB

6. EDWIN LANG, *Captain*
   B. C. FLEMMING
   LEROY ANDERSON
   ALFRED S. CUMMINGS
   CARL J. MARX

7. K. F. RANGER, *Captain*
   H. GILLER
   SAM READ
   ART FELL
   A. SUBIA

8. JOE SLAVIK, *Captain*
   GEO. BOLAND
   FRANK M. GERTISER
   D. W. PATTERSON
   R. S. SPENCER

9. A. H. HOFFMAN, *Captain*
   E. A. BRANCHOFSKY
   E. A. RUTT
   C. E. TEFFT
   W. L. WILLSON

10. WM. PETERSON, *Captain*
    H. S. BRANDT
    J. O. GANGLER
    F. H. HARTLEP
    C. J. OXFORD

NOTICE TO PROSPECTIVE MEMBERS

After January 1, 1933, the initiation fee for membership in the American Society of Tool Engineers advances to $5.00. You have until that time to take advantage of the present fee of $3.00, which not only pays the initiation fee, but also includes dues for the balance of the year 1932. If you wish to take advantage of this offer, kindly forward your application and check to the Secretary of the ASTE, or to any member of the various membership drive teams. Do not delay, but act at once.

If you desire an application blank, kindly fill in the following coupon, and mail it to the Secretary of the ASTE, 8316 Woodward Ave., Detroit, Michigan, and full particulars will be mailed in return.

MEMBERSHIP COMMITTEE.

SECRETARY ASTE,
8316 Woodward Ave.,
Detroit, Michigan.

Kindly send me full particulars regarding membership in the American Society of Tool Engineers.

Name .....

Street .....

City and State .....

Occupation .....

Company .....

THE MANUFACTURE OF GLASS

by C. B. SCHAFER

An unusually interesting educational sound moving picture, just released by the Libbey-Owens-Ford Glass Company of Toledo, Ohio, was shown at the November meeting, November 10, at the Detroit Leland Hotel under the sponsorship of the Libbey-Owens-Ford Glass Company.

Flat glass as manufactured by the Libbey-Owens - Ford Glass Company of Toledo, Ohio, comprises three main divisions; first drawn sheet or window glass; flat drawn or cast, ground and polished plate glass; and safety sheet and safety plate glass.

Window glass is manufactured by the continuous drawing method, a typical Libbey-Owens-Ford development (See Fig. 2). The raw materials or batch is fed into the front of the furnace and brought up to the proper temperature. The molten glass flows through a refining chamber to the back of the furnace where it is drawn up over bending rolls into the lehr. Here it is slowly annealed to room temperature, leaving the lehr at the cutting table where it is cut into 72 inch squares and moved by means of a conveyor to the washing machine. After this operation, it is ready to be cut to commercial sizes.

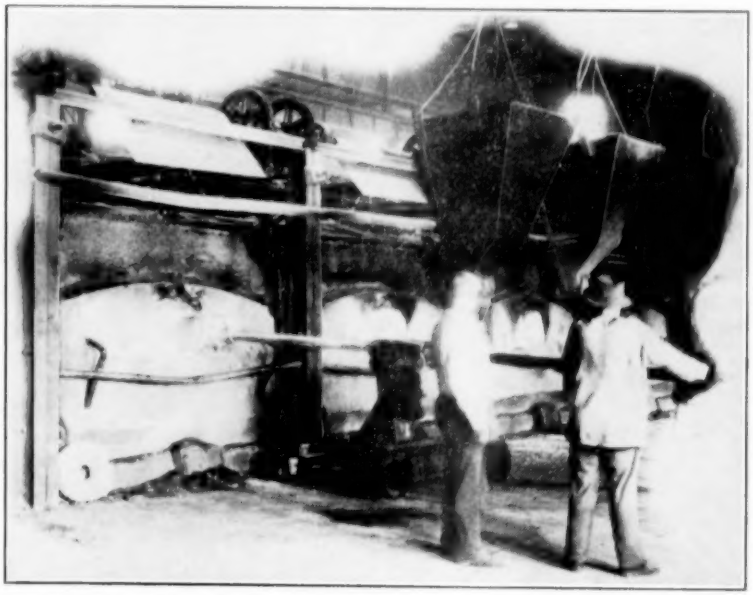


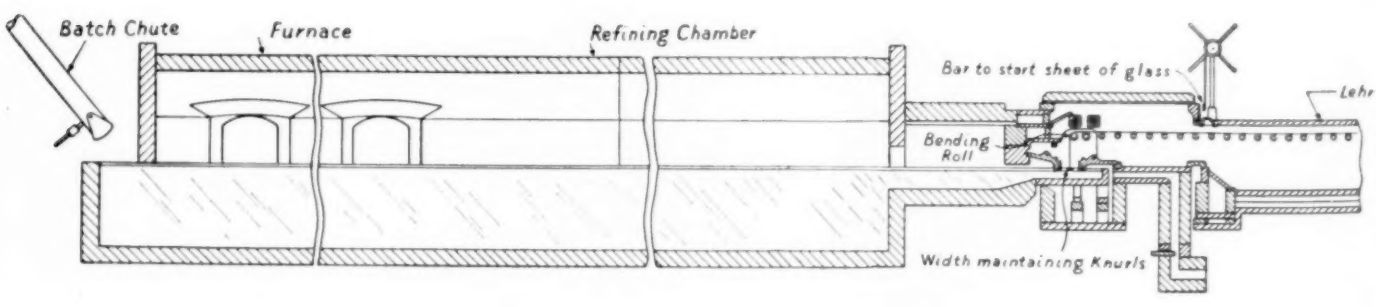
Fig. 1—Glass being heated in the furnace

Glass blanks drawn in this way are used for window glass and glass blanks obtained in a similar manner, after proper grinding and polishing, give a crystal luster plate glass. The manufacture of flat drawn glass was clearly shown in the first reel of the picture.

The second reel showed the rolling method or Bicheroux process. The molten glass batch, carried to the rolling machine in large crucibles, is fed into a pair of revolving rolls. The rolled glass blanks are carried away over a chute to a synchronized table. Rough blanks, 126 inches square, are obtained in this manner. The method of annealing is the same as for window glass.

Grinding and polishing of the glass is done also by a continuous method. The glass blanks are loaded flatwise on moving tables and carried underneath a series of revolving grinders and polishers.

Safety glass consists of two layers of plate or sheet glass and an intermediate sheet of thin plastic. In manufacture, the glass is provided with an adhesive material and the glass-plastic-glass sandwich welded together by means of heat and pressure. The edges of the finished glass are sealed with a water-proof material.



THE TOOL ENGINEER'S PLACE IN MASS PRODUCTION

By O. B. JONES, President, Detroit College of Applied Science

The tool engineer's duties relate to tools. A tool is any implement used by man to make his efforts more efficient. The word tool as used in connectoin with tool engineering today applies only to tools used in the manufacturing processes, that is the tools used in a factory. Automobile factories are as highly developed as those producing any other article, and bring into play all the functions of tool engineering. In what follows we shall therefore have in mind the automobile factory.

EQUIPMENT OF MODERN MASS PRODUCTION PLANT

The automobile factory is equipped with standard machines principally. This is due to the fact that the design of the car is altered, usually, each year, and the cost of designing and building a special machine to produce a part of the car which may be in production for only a year is so great that the saving brought about by the special machine will not justify the investment. When the design of a part of the car is changed, or a different part is to be made on a machine, a new device for holding the part on the machine must be designed and built.

The system of vices, clamps, and locaters designed to hold the part of the car in its proper place on the table of the machine is called a fixture. If the part is located in a device attached to a revolving spindle of the machine, the device is called a "chuck." The instrument which acts directly upon the part to remove metal or to otherwise change the shape of the part is usually called a "perishable tool." The word tool has often been used to include all devices used on a machine to enable it to do its work more efficiently on any part of the product being made. The meaning of this word becomes broader each year, through usage, and is now used to include all machines of every description used directly to produce the part. We may conclude then that all equipment in a factory which acts directly upon a part being manufactured, to change any of its physical characteristics, is a tool. The tool engineer's concern is with all mechanical equipment and manufacturing processes in the plant.

BREAKING UP AND CLASSIFYING OPERATIONS

The tool engineer's first step in analyzing a part for mass production is to break up and classify all the elemental operations that must be performed in the production of the part, so that each operation can be performed on the simplest type of machine operated by an unskilled workman. Duplicates of each part must be interchangeable: that is, each part must be accurately made so that it can be assembled indiscriminately into any car for which it is designed.

The human element must be eliminated from the process wherever possible, to assure absolute uniformity of results. The supplanting of human hands by machines reduces the cost of the product and thereby enlarges the market. Mass production is possible only when the selling price of the manufactured article is sufficiently low to enable the masses to buy it conveniently.

The man who analyzes each part before putting it into production, who lays out the sequence of operations for producing it, selects the machines, and plans the general design of tools to obtain a balanced production of parts, at the lowest possible cost compatible with specified quality, is known as a tool engineer.

SPECIFIC KNOWLEDGE THE TOOL ENGINEER MUST POSSESS

By taking separately the duties of the tool engineer, we can roughly sketch an outline of what he should know.

(1) He analyzes the part prior to putting it into production. He must study the part to determine its function in the assembly into which it fits. He must study the design of the part to determine whether it could be altered to reduce its manufacturing cost. This may carry him into a problem in mechanics or the strength of materials, as well as cost estimating, involving time study, tool or die design, and many incidental cost items.

(2) He lays out the order of machining operations. The proficiency or skill with which this function is performed is considered by most tool engineers as being the best criterion

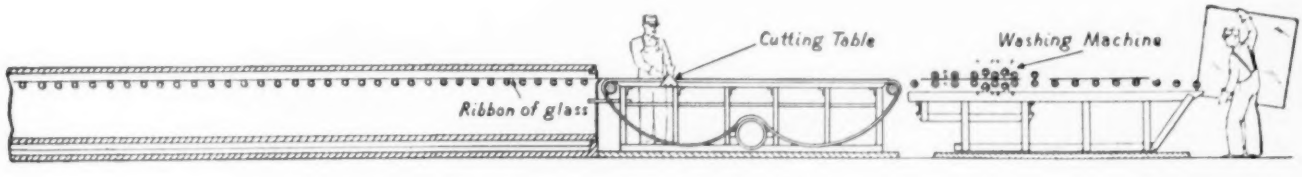


Fig. 2. Manufacture of window glass

of the tool engineer's ability. The particular knowledge required can only be gained by study of the order of operations of similar parts which have been manufactured. Skill comes only through the process of planning the operations after careful study of similar pieces in production. A wide knowledge of manufacturing and plant layout is required.

(3) He selects the production machines. This function of tool engineering consists of more than simply using the machines immediately available. It is not enough merely to determine that the machine loading is such that a certain machine can be used. It amounts to more than using the line-up of machines which was used on a similar part, because they happen to be set in line as needed. There comes a time in the life of every machine when it should be scrapped because of obsolescence or because its up-keep cost is excessive. At this juncture the tool engineer should determine the suitability of the machine, not just on the basis of whether it can do the job, but rather on the basis of whether it can be used economically. A knowledge of the formulas and procedure in such cases must be possessed by the tool engineer.

(4) He indicates the design of the tools, that is the fixtures. The tool engineer should not leave the entire design of the fixture up to the tool design department. The tool engineer should indicate by a free hand sketch, or reference to some other fixture, the general design in order that the life, accuracy, strength, and ultimate cost may be comptaible with the requirements. The use of certain formulas used by accountants and engineers is here indicated. He must be experienced in their use.

(5) He must obtain a balanced production. He must know how to estimate the time required to perform the operations on the machines selected, in order that he can advise the tool designer whether the fixture is to be a single or multiple type, and whether index bases need be designed, and so on.

(6) The part must be produced at lowest cost. All possible ways of producing the part should be considered and the cost of performing each operation estimated from past records. The knowledge required is indicated by the duty specified.

(7) Specified quality must be obtained. This is one of those functions which seems to be most difficult for the young tool engineer to discharge exactly, because of a lack of fundamental knowledge of the degree of accuracy with which certain machines perform their operations. It is the misinterpretation of this item which often runs the tool cost to unnecessary heights. The question of tolerance and gaging enters here and obviously constitutes one of the most important considerations of tool engineering.

GENERAL KNOWLEDGE THE TOOL ENGINEER MUST POSSESS

A knowledge of machine shop practice, inspection methods, and gages must be had. The tool engineer should understand the operation and operating characteristics of every machine in the plant. It is essential that he be of a mechanical bent of mind, possessing a mechanical sixth sense which enables him to grasp at a glance and retain in his mind the possbiilities, purpose, construction, and method of operation of any machine however complex.

The tool engineer should understand the fabrication of metal parts of the automobile, from the time the ore is mined until the manufactured part is ready to be assembled into its final car assembly.

He must have a thorough knowledge of economics and cost calculating, for he must ever be weighing the initial cost of a contemplated method or design, that is, the first cost of building a machine or tool, against the time and money saved in using the new method or tool.

The outline of the duties of the tool engineer, previously given, indicates rather closely what his training should be. For best results his mathematical training should include calculus. He should without question be well versed in mechanics and the strength of materials. He must be taught drafting, tool, die and machine designing. He must be taught time and motion study, work routing, production planning, cost finding, and economics. He should have a fair knowledge of business organization and executive functions.

No position in the manufacturing organization requires more real salesmanship and diplomacy than that of the executive tool engineer. This is true because new ideas are his principal product and they are about the hardest things in the world to sell. Obviously, training along the lines of human behavior, psychology, salesmanship, and public speaking would materially benefit him.

SAVINGS THAT CAN BE ACCOMPLISHED

What a tool engineer can accomplish is best illustrated by a hypothetical example. Let us imagine that his job is to tool up a valve for a six cylinder engine for an annual production of 500,000 cars. Each engine has 12 valves, so that the total year's production would be 6,000,000 valves. Assume that he saves 1 second on each of the six operations on the valve. This slight saving in time on each valve is equivalent to the labor of four men for one year. There are around 4,000 details on an average six-cylinder car, and often as many as 15,000 parts. If we assume a low average of four operations to each part, 60,000 operations are required in the making of one car. If the annual production is 500,000 cars, 30,000,000,000 operations are performed each year. If one second is saved on each operation, a total saving in labor of 3,412 men working one year is effected. This amounts to approximately a saving of $7,000,000 a year, or $14 per car. This may be asking too much of the tool engineer, but we cannot overlook the fact that our present highly developed science of mass production is attributable more to the tool engineer and tool designer, by whatever title he has been known in the past, than to any other single individual in the whole organization.

Philosophic Critic Santayana Asserted: I should be ashamed to countenance opinions which, when not arguing, I did not believe. It would seem to me dishonest and cowardly to militate under other colors than those under which I live.

Realist Nietzsche Warned: Will nothing beyond your capacity; be not virtuous beyond your ability; and demand nothing of yourselves contrary to probability.

Tool Engineering Bulletin No. 11

DEEP HOLE DRILLING—SPEEDS AND FEEDS

The planning of drilling operations often fails to take into account the depth of hole to be drilled, and its influence on permissible rates of feeds and speeds.

In Engineering Bulletin No. 7 a table of feeds and speeds has been given, that can safely be followed for average conditions. If the hole to be drilled equals or exceeds three times the diameter of the drill, the operation falls in the deep hole drilling class, and some adjustment of feeds and speeds is necessary in order to secure maximum efficiency.

In its final analysis it is entirely a matter of conducting away the heat generated, and to prevent its accumulation. It is an evident fact that if less heat is conducted away than is generated, the drill will eventually overheat and be destroyed.

While the nature and amount of coolant applied to a given drilling operation will affect the depth of hole that can safely be drilled at the feeds and speeds given in Bulletin No. 2, the above mentioned depth of three diameters is a good point to begin the stepping down. This applies particularly to the speed.

The table given below will serve as a guide to the proper reductions as the depth of hole increases:

SPEEDS

Depth of hole		Reduction of Speed
3 times drill diameter	—	10%
4 times drill diameter	—	20%
5 times drill diameter	—	30%
6 to 8 times drill diameter	—	35% to 40%

FEEDS

Depth of hole		Reduction of Speed
3 to 4 times drill diameter	—	10%
5 to 8 times drill diameter	—	20%

If excellent cooling conditions are present the above rates may be increased; but if there is little or no provision for cooling it may be necessary to step down even lower than the figures given above.

Always keep in mind that a somewhat lower rate, constantly maintained, will show more production per day than a high rate with long and frequent interruptions. In the latter case, too, the tool costs will be much higher.

Courtesy of C. J. Oxford

National Twist Drill & Tool Co.
Detroit, Mich.

Tool Engineering Bulletin No. 12

DRILLING OF MOULDED PLASTICS

In the last few years there has been developed a series of materials known as Moulded Plastics. Many of these materials are phenol compounds. They are designated by various trade names of which Bakelite probably is the best known. These materials are being used for an increasing number of articles and purposes.

In the preparation for their final uses a certain amount of machine work is often necessary. Drilling of holes probably is the most common of these machining operations.

It has been found that these materials are abrasive, and are therefore very destructive of tools. Further, the chips tend to cling to the tools, causing packing and overheating.

To overcome these tendencies special designs of drills have been developed, known as Bakelite drills. These drills have wide flutes highly polished, with a somewhat slow angle of spiral, and are usually given a special heat treatment to increase their resistance to abrasion. In typical instances it has been found that these drills will drill Moulded Plastics very successfully and will outperform the conventional types of drills several times.

Drilling speeds should be from 100 to 300 surface feet per minute depending on the diameter and depth of holes. Feeds per revolution should be maintained approximately the same as those for drilling steel, though in some cases this may be increased considerably. Drilling is done dry as any liquid applied for cooling purposes will cause the chips to gum up, and will produce a messy condition all around.

When trouble is encountered in the drilling of these materials it is always well to secure competent advice on the proper design of drills and other operating conditions. A slight change in drill design will often make a very great difference in performance.

Courtesy of C. J. Oxford

National Twist Drill & Tool Co.
Detroit, Mich.

HOW THE DESIGN ENGINEER VIEWS MANUFACTURING

By Alex Taub, Development Engineer, Chevrolet Motor Co., Detroit

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That the production specialist's day is over, as has been said, is certainly not true. We believe that the need for production ingenuity is greater today than ever before. Engineering standards have gone up, perhaps because business is down.

The engineer looks to the shop for major assistance in the realization of his improved ideals. He expects from the shop progress along two distinct lines:

(1) Voluntary reduction in variations

(2) Increased mobility for change.

By (1) is meant a reduction in variation from the mean specifications, such as usually is represented by tolerances, specified and otherwise.

A group of trouble-makers can be found in structural variations. These can best be illustrated by considering a crankcase and a cylinder block. The walls of these units vary in thickness approximately 3/64 in. If this allowance is included in the specifications as a tolerance, it usually is all plus, which means weight, and somebody must pay for the iron. If this variation is not allowed for in the specifications, we must deal with a possible weakness. This weakness may produce resonance and roughness, and this is not in keeping with current engineering requirements.

A structure like a crankcase is certain to incorporate critical locations which are supersensitive to metal variations. A good crankcase is carefully developed or, we might say, calibrated as is a carbureter, to obtain the maximum structural effect for the minimum weight.

To go through a crankcase with a fine-tooth comb is useless unless some assurance can be had from the shop that the dimensions can be held. When we bear in mind the fact that it is possible to effect a structural gain of 40 per cent in a crankcase by an addition of 3 per cent in weight, the importance of variation can readily be seen.

These variations include those of the foundry and the machine-shop. The machine-shop can help by means of accurate location points and the rapid check-up of castings as they are received. This will avoid the piling up of unsatisfactory stock, which usually is absorbed in production.

Machine-Shop Variation from Specifications

The characteristics of a powerplant are largely controlled by the accuracy of the centers, roundness and straightness of cylinder and crankshaft and camshaft bores. Considerable progress has been made along these lines. However, if the most is to be made of every square inch of bearing area, more attention must be given to the variations at these places. Engineering decisions are based upon tests of various kinds, and, if the manufacturing variations are not discounted, trouble may follow. If the variations are large, the effect of the investigation is lost.

Another important variation that gives considerable field trouble is that from true concentricity of valve-stem guide and bosses with the valve seat throat. Eccentricity here results in poor valve life and generally an engine performance that is below par. I believe that opportunity exists for development of tools for machining these parts. Improvement in accuracy would be as far reaching in its satisfaction as eccentricity has been annoying in the field and to the engineer.

Machinists in the shop appreciate quiet tappets, and, although concentric valve seats are not a cure-all for noise, the development of a good, quieting ramp on the camshaft is impossible if the valves are "acting up" on their seats. Here is an opportunity for the machine-tool maker to point the way with new tools or methods for more concentric valve seats. This means quieter, smoother engines and maximum power for a longer operating period. It presents an outstanding opportunity for more result per dollar.

Crankshaft Variation Causes Engineer Concern

Variations in the crankshaft are sources of concern to the engineer. The crankshaft is literally infested with tolerances to cover manufacturing variations and still more that are not listed. No doubt the specified variations are necessary today; but what improvement may we expect? Are you doing anything about straight journals on crankpins and main bearings? What about smoothness of finish, and what is being done to reduce the required tolerance on diameter? What is being done to narrow down variations here in crankpin index and radius?

This last point is today the outstanding element in heavy corrections for out-of-balance conditions. Sometimes we note heavy grinding on cheeks that is all out of proportion to forging variation. This takes time and may weaken the shaft structurally, and, because of the time involved, tends to create a shop demand for wide tolerance for balance. With proper cooperation between engineer and forge plant, arrangements can be made whereby the crankshaft forging will be ideal for balancing. However, no forging compensation can be made for position error in crankpins. This presents another opportunity for the machine-tool man to show what he can do.

A better understanding of crankshaft balance is required. Today crankshafts are being held to

½ in-oz. out of balance, which is very good; but the important point is, where is the out of balance? The shaft, though checking to ½ in-oz. out of balance, may actually be 24 times this much under operation if consideration is not given to the position of the out of balance and a couple is permitted t oexist. Increased tolerance for out of balance is preferred to incorrect position.

The engineer and the forge shop can collaborate to the extent that all forgings shall be heavy in the desired plane. This would still mean nothing if crankpin-position error is permitted. Very little position error of the pins can create considerable out-of-balance effect.

Reciprocating parts of an engine are respected by both the shop and the engineer but, like the crankshaft, they are smothered in tolerances, with resulting weight variations. Selective assembly is the present way out. However, what is being done to bring all rods and pistons to one weight? We need automatic weighing equipment that is easy to use and which will indicate how much must be taken from each piston to bring all to the same weight. This will leave us with only the fit variation for selection. Likewise, connecting-rods should be designed and manufactured to a uniform weight, so that any rod will fit any engine in the field and shop. This means maintaining consideration of interchangeable fits. Rods have been made uniform in the matter of fit; now let us have uniform weight.

We could go through every piece of the car and raise questions as to what is being done to reduce tolerances. For instance, spline shafts are an endless source of trouble because of the tolerances required under present methods of fabrication. What shall be done about it? To ask is easy, but to execute no doubt is difficult.

NEED OF MOBILITY FOR CHANGE

To change with the trend is second in importance only to creating the trend. To do either we must be able to make changes without the tremendous expense of the immediate past. The greatest obstacle to mobility to change is expensive tools. I do not mean by this that high-grade machine-tools cannot be used; there can be no return to the file and solder iron. I mean that both large and small tools must be designed with facility for change.

One of the worst examples of immobile tools is cylinder-boring equipment provided with fixed heads. In the last few years, as you know, the reamer has been applied to the engine of our industry, and in most cases the larger bore was obtained without any change in bore centers. Reduction in water-passage area was the result, with its many evils for foundry and field. Uneven cooling of bores, which follows such restriction, will give trouble through the life of the car. It breeds blow-by and hot oil, compression leaks and power loss, worn piston-rings and excessive oil consumption. Such an engine may be bigger, but it certainly is not better. However, the *centers have been saved.* Fixed-center machinery is to blame.

We must have rugged accuracy without fixed centers. This principle applies throughout. Progress may demand the shifting of one hole in a group. Fixed-center machinery may make the change prohibitive or at least costly, hence a product that is unsatisfactory at some point is continued through production because of the cost of changing. This does not mean that we must go back to the single-spindle machine; it calls for equipment with adjustable centers without sacrifice of accuracy.

Location holes for positioning the product in the jigs is necessary, but suppose that these dowel holes are in such a location that a needed change would require that they be moved a little. Today, in some shops, that would be a catastrophe; it would affect every jig in the cylinder-block line. Why should this be so? Location dowels should be incorporated in fixtures in such a way that they could be moved or firmly fixed at will in the shop.

SHOP RELUCTANCE TO CHANGE OF METHOD

The mental attitude of the men in the shop to change in machining methods to facilitate changes in the product is worthy of mention. Suppose it becomes necessary to increase the rigidity of a crankshaft, which may require cheeking. Considerable protest arises in a shop that is not cheeking the crankshaft, which is a difficult and unsatisfactory operation. Why? Probably because suitable tools are not available or the sequence of operation would be disturbed. The shop is entitled to its "rathers," but shop habits also must undergo development in mobility to change.

Good engineering ideas or principles often are doomed because the designs cannot be made economically if at all. But this is the day of new ideas; if competition is the life of trade, new ideas are the life blood of competition.

The suggestion has been made that the engineer call in the machine-tool specialist to collaborate on designs while they are still liquid. This might lead to the successful production of an item heretofore regarded as beyond redemption.

What would our associates in the production department do if the engineer told them how to do their job or where they should buy machine tools? Yet new ideas must be given consideration even when apparently impractical from the producing standpoint. The outside specialist, with his incentive for new-tool sales, should be brought into consultation, but by the shop. Rather than discard a new item, the shop should pass the problem of its fabrication out among the various tool companies in which it has confidence. Thus, casting the bread of our ideas upon the waters of machine-tool genii may result in a return other than just wet bread.

Intimate Engineering and Shop Contact Vital

We ask for a *voluntary decrease in variations* and

improved mobility to change. These must not be conflicting requirements. One without the other would be insufficient. Appreciation of each of these elements exists today. However, they need more consideration, particularly when appropriations for new or changed products are in the offing. If new investments are in order, let us give consideration to these principles. Who knows but that the promotion of these very principles may help the appropriation along.

The fact has become increasingly evident that intimate contact between the shop and the engineering department is needed to build the proper appreciation of each other's problem. It is essential that the engineer shall know his shop and shop man, so as to temper his suggestions to prevailing conditions. It is just as vital that the shop man be intimate with engineering test results, so that he can see the parts he is producing in the light of their functioning. Test results, or even seeing tests conducted, may influence valuable suggestions as to improved design that will *be easily produced good.*

Pragmatic William James asserted: I firmly disbelieve, myself, that our human experience is the highest form of experience extant in the universe. I believe rather that we stand in much the same relation to the whole of the universe as our canine and feline pets do to the whole of human life. They inhabit our drawing-rooms and libraries. They take part in scenes of whose significance they have no inkling. They are merely tangent to curves of history, the beginnings and ends and forms of which pass wholly beyond their ken. So we are tangent to the wider life of things.

A TOOL ENGINEERING PROJECT

By SVERRE BERG, FLOYD CARLSON, CLARENCE ERICKSON, HERBERT ROYLE, LEONARD SPRENGER, TOM TOMAKICH, KENNETH WATSON, LOUIS WOKAS.

(Concluded from last issue)

MAIN ASSEMBLY

The first assembler, at final assembly station F.A.1, takes the base from the base and arm drying rack and places it on the flat belt conveyor. He takes a column from the conveyor, and puts it into the hole in the base. From a stock bin near the conveyor, he takes a $\frac{3}{8}$—16 square head set screw, and with a socket wrench tightens it in place against the drill spot in the column. The same assembler also assembles the arm to the column, and puts the arm lock lever and bolt in place. The arm lock levers are trucked from the small parts drying rack and placed in the stock bin.

At station F.A.2, the second assembler puts the spindle sub-assembly unit in place.

At station F.A.3, the feed screw sub-assembly unit is assembled to the drill press with $\frac{3}{8}$—16 hex head screw, taken from the nearby stock rack.

The main conveyor brings the fourth assembler, at station F.A.4, the pulley shield. He assembles it to the arm with a screw and washer, which are taken from the nearby stock rack. The same assembler also assembles the spindle pulley to the arm.

The partially assembled drill presses now pass under the bridge (see Fig. 27), and are shoved onto the narrow gauge roller conveyor at right angles to the power conveyor.

At F.A.5, two assemblers assemble the motor and motor pulley unit to the arm. The pulley has been previously assembled to the motor after the machining of the pulley.

The next assembler, at F.A.6, puts the belt in place, and screws the chuck to the spindle, by starting the motor and holding the chuck under the spindle. One out of every 10 presses is then tested under load.

At F.A.7, a man puts the finished drill presses into crates carried by the main assembly conveyor, and nails up the open side. A conveyor then carries the crated drill presses to the shipping station exit.

CRATES

The lumber for the crates is brought in daily at station K, and piled on the floor as shown in Fig. 27. A circular saw (Q1) is used to saw the lumber to length. It is then corded up beside each of the assembly benches Q2, Q3, Q4, and Q5. Three lengths of board are used to make the crates and their covers. The covers are sawed by the operator at Q1, and stacked beside the benches. Four men are required to build the crates, which when finished are stored on the opposite side of the benches.

CONVEYORS

The final assembly conveyor is a plain type belt conveyor 18" wide. This assembly line is 104 ft. long. It is motor driven at a speed of 8 ft. per minute. To keep pace with our production, two drill presses must leave the conveyor every minute; therefore, there is one drill press for every 4 ft. of conveyor length.

Since the belt is 104 ft. long, there will be 104 ÷ 4 = 26 drill presses on the conveyor at any given time. A drill press without the motor weighs

37 pounds. Hence, there will be a load of 26 x 37 = 962 pounds carried by the conveyor. The belt is supported by steel plates having a coefficient of friction of 0.3. The pull required to start the conveyor under load will be 962 x .3 = 288.6 pounds. The horsepower required will be

$$\frac{288.6 \times 8}{33{,}000} = \frac{1}{14} \text{ HP.}$$

A one-horsepower motor was recommended by the manufacturers of the conveyor, and, being but little more expensive to operate than a smaller horsepower motor, was used for the purpose of driving the conveyor.

The pulleys on the conveyor are 2 ft. in diameter, and hence must travel 8 ÷ 2 pi = $1\frac{1}{3}$ rpm. As the motor has an rpm. of 800, the speed ratio between the motor and the conveyor pulleys will be 800 ÷ $1\frac{1}{3}$ = 600 to 1. A reducer was selected which would give this reduction.

Fig. 33 shows a diagrammatic side view of the motor driven rack used for drying base and arm castings after painting.

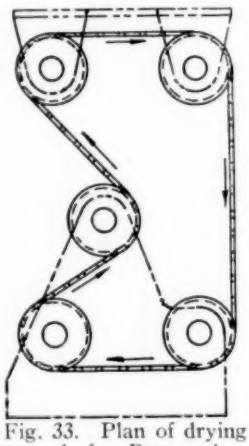

Fig. 33. Plan of drying rack for Base and Arm castings.

The roller stand conveyors used in the plant have a grade of $\frac{3}{16}$" per ft. The widths of these conveyors generally are 18" or 24", but in two cases a width of 6" is used.

Our plant was so extensively conveyorized because of the obvious savings in time and labor effected thereby. The total cost of our conveyors was $15,200.00. A conservative estimate places the number of truckers that would be required to do the work of the conveyors at 9. Assuming a wage of $1500.00 a year for a trucker, the conveyor system will pay for itself in

$$\frac{\$15{,}200.00}{9 \times \$1500.00} = 1.12 \text{ years.}$$

COST ANALYSIS

And now we come to the most pleasant part of our task; calculating the cost of our product, and hence arriving at some idea of the imaginary profits we are going to reap from our imaginary enterprice. Imaginary profits have their disadvantages to be sure, but one of their undeniable advantages is their immunity from the bogey of income and excess profits taxes.

The cost of manufacturing our drill press was resolved into five items: material cost (including freight and handling, and interest), direct labor cost, indirect machining cost, tool and fixture cost, and assembling cost. This is illustrated in Fig. 34.

As we used the expedient of a machine hour rate for distributing the indirect expenses, such as factory and equipment cost, and indirect labor cost,

COST OF DRILL PRESS

DETAIL	MATERIAL COST PLUS FREIGHT, HANDLING & INT.	DIRECT LABOR COST	INDIRECT MACHINING COST MACHINE HOUR RATE TIMES CUTTING TIME	TOOL AND FIXTURE COST	COST OF DETAIL
COLUMN	$ 0.196	$ 0.00401	$ 0.03781	$ 0.00396	$ 0.24178
BASE	0.36096	0.01738	0.03807	0.01632	0.43273
ARM	0.40428	0.06665	0.13529	0.01157	0.61779
RACK	0.0320	0.01290	0.03496	0.01061	0.09047
SPINDLE	0.0150	0.01198	0.03284	0.00428	0.06410
FEED SCREW	0.0130	0.01243	0.02548	0.00180	0.05271
THRUST PIN	0.0008	0.00193	0.00898	0.00043	0.01214
FEED LEVER	0.0168	0.00716	0.01187	0.00190	0.03773
FEED PINION	0.0200	0.02577	0.07309	0.0122	0.13106
ADAPTER BUSHING	0.0068	0.00642	0.01045	0.00166	0.02533
SPINDLE BUSHING	0.002	0.00321	0.00928	0.00159	0.01608
CAP	0.01208	0.00232	0.00508	0.00175	0.02123
ARM LOCK LEVER	0.01108	0.00274	0.00763	0.00107	0.02252
FEED SCREW HANDLE	0.01108	0.00528	0.01069	0.00130	0.02835
PULLEY SHIELD	0.04535	0.00371	0.00938	0.00089	0.05933
MOTOR PULLEY	0.09000	0.01187	0.0692	0.0114	0.18247
SPINDLE PULLEY	0.1350	0.01817	0.11425	0.0207	0.28812
TOTAL COST OF UNASSEMBLED DRILL PRESS					$ 2.32394
ASSEMBLING COST					
LABOR COST					0.03461
MACHINING COST - CONVEYOR					0.24177
TOOL AND FIXTURE COST					0.00025
STANDARD PARTS COST - INCLUDING MOTOR					6.8203
TOTAL FACTORY COST OF ONE DRILL PRESS					$ 9.42087

Fig. 34. Cost analysis of Drill Press.

the item above called "indirect machining cost" does not bear a very apt title, since practically the entire overhead burden of the plant, along with the bona fide machine expense, goes into this item. But a more definitive title enumerating all the many different expenses crowded under this one inadequate heading, "indirect machining cost," would be long and unwieldy, so the lesser of two evils was chosen, and simplicity was given the preference over verbal exactness. The other expense factors listed above have titles fairly descriptive of their content.

By material cost is meant the cost of the raw material of which the various details of the product are actually made, plus the cost of freight and handling, and the interest. The paint used on the cast iron details of the drill press, to hold to the letter of our definition, was treated as one of the "direct materials." Hence, in the tabular form, Fig. 34, the figure representing the cost of the raw materials for the painted details will include the cost of the paint. It was only a matter of simple arithmetic to compute the cost of the material, for say one column or one spindle, from the cost of a shipment of the material. If, for instance, the shipments of material for a certain detail are made once a month, the material cost for that detail can be found by dividing the total cost of the shipment including freight, handling, and interest at 3 per cent by the number of pieces produced in a month. An interest rate of 3 per cent is used because we are computing interest on a quantity that is gradually diminishing to zero as the shipment of stock is being consumed. The average interest rate will be 6 per cent ÷ 2 = 3 per cent.

The direct labor cost per piece was found by finding the labor cost of each of the operations on the part, and taking their sum. The formula

$$C = \frac{R}{P}$$

was used to determine the labor cost per operation. In the formula, C is the labor cost, R the base wage rate per hour, and P the production per hour on the particular operation. The derivation of the formula is as follows: If P represents the production per hour, the reciprocal of P will represent the time required for one performance of the operation. The wage rate per hour multiplied by the reciprocal of P will then give the labor cost of the operation. The base wage rates for different types of work were fixed in accordance with the scale followed in an actual manufacturing plant, which for reasons of prudence we cannot name here.

Fig. 35 shows the various burdens we have worked into the indirect machining cost, through the medium of a machine hour rate for each machine in the plant. It should be mentioned that the power driven belt conveyor, the washing machine, and the power driven drying racks were treated as machines, and given machine hour rates.

The indirect machining cost for a given operation was found by multiplying the machine hour rate of the machine used by the actual cutting time. Adding together the indirect machining costs for the various operations on a part gives the total

PLANT AND EQUIPMENT COST

ITEM	DEPRECIATION RATE	INVESTMENT	YEARLY INTEREST DEPRECIATION & OTHER CHARGES
LAND		$ 7,000.00	
FACTORY BUILDING	5%	18,000.00	$ 900.00
HEATING SYSTEM	5	2,080.00	104.00
PLUMBING	5	1,880.00	94.00
FURNITURE	10	150.00	15.00
BENCHES	33⅓	688.75	229.00
PAINT TANKS	33⅓	35.00	11.67
STOCK RACKS	33⅓	186.50	62.17
CONVEYORS—NOT POWER DRIVEN	33⅓	9,962.00	3,320.00
TIME CLOCK	20	100.00	20.00
SUB-ASSEMBLY BOOTHS	10	1,200.00	120.00
STOOLS	10	220.00	22.00
TRUCKS	10	360.00	36.00
TOTE BOXES	33⅓	400.00	133.33
WASTE CANS	33⅓	6.80	2.26
LOCKERS	10	562.50	56.25
AIR COMPRESSOR	33⅓	170.00	56.67
CYANIDE EQUIPMENT	20	180.00	36.00
INSTALLATION		500.00	
TOTAL INVESTMENT IN PLANT AND EQUIPMENT		43,681.55	
STATIONERY AND PRINTING PLUS INTEREST			515.00
TELEPHONE			75.00
WASH ROOM SUPPLIES PLUS INTEREST			103.00
INTEREST ON TOTAL INVESTMENT IN PLANT AND EQUIPMENT			2,620.89
INSURANCE			2,620.89
TAXES			873.63
WATER			150.00
LIGHT			468.00
HEAT			380.00
GAS			75.00
MAINTENANCE			436.82
TOTAL YEARLY PLANT AND EQUIPMENT COST			13,597.16
PLUS 10% FOR CONTINGENCIES			1,353.72
TOTAL			14,890.88

TOTAL FLOOR SPACE OCCUPIED BY PRODUCTIVE MACHINES — 2160 SQ. FT.

F = YEARLY PLANT AND EQUIPMENT COST PER SQUARE FOOT OF PRODUCTIVE FLOOR SPACE ——— $6.8939

INDIRECT LABOR COST

EMPLOYEE	No. REQUIRED	YEARLY SALARY	TOTAL YEARLY COST
SUPERINTENDENT	1	$ 4000.00	$4000.00
FOREMAN	2	2500.00	5000.00
TYPIST AND OFFICE GIRL	1	1500.00	1500.00
TIME CLERK	1	1800.00	1800.00
BOOKKEEPER	1	1800.00	1800.00
ENGINEER	1	3000.00	3000.00
OFFICE BOY	1	750.00	750.00
TRUCKER	1	1500.00	1500.00
LABORER	3	1500.00	4500.00
CHIEF INSPECTOR	1	2500.00	2500.00
STOCKKEEPER AND TOOL CRIB ATTENDANTS	4	1800.00	7200.00
INSPECTOR	4	1800.00	7200.00
SHIPPING CLERK	1	2000.00	2000.00
PURCHASING AGENT	1	3000.00	3000.00
TOOL ROOM FOREMAN	1	2500.00	2500.00
HEAT TREAT MAN	1	1800.00	1800.00
MACHINE OPERATORS IN TOOL ROOM AND REPAIR MAN	5	2000.00	10000.00
PERSONNEL MAN	1	2500.00	2500.00
WATCHMAN	1	1600.00	1600.00
TOTAL INDIRECT LABOR COST			72150.00

TOTAL MACHINE RUNNING HOURS PER YEAR — 92,945

G = INDIRECT LABOR COST PER MACHINE RUNNING HOUR $.759

TOOL ROOM COST

EQUIPMENT	DEPRECIATION RATE	INVESTMENT	DEPRECIATION INTEREST, ETC. PER YEAR
DRILL PRESS		$ 575.00	
MILLING MACHINE		2800.00	
CUT OFF SAW		65.00	
GRINDER		175.00	
LATHE		1250.00	
SHAPER		1860.00	
HARDENING FURNACE		160.00	
ARBOR PRESS		24.00	
WATER AND OIL TANKS		4.50	
SURFACE GRINDER		875.00	
ANVIL		18.00	
FORGE		30.00	
DU-MORE GRINDER		125.00	
EXTERNAL GRINDER		875.00	
TOTAL MACHINE OUTLAY	33⅓%	6,828.50	$2276.17
MOTORS FOR MACHINES	33⅓	400.00	133.33
CRIB, TOOLS, CUTTERS, VISES, RACKS, BENCHES, POWER, INSTALLATION, ETC.	50	3,000.00	1500.00
TOTAL TOOL ROOM INVESTMENT		10,228.50	
INTEREST ON TOOL ROOM INVESTMENT			613.71
TOTAL YEARLY TOOL ROOM INVESTMENT			4523.21
PLUS 10% FOR CONTINGENCIES			452.32
TOTAL			4975.53

TOTAL OCCUPIED PRODUCTIVE FLOOR SPACE OF PLANT ——— 2160 SQ. FT.

H = TOOL ROOM COST PER SQUARE FOOT OF PRODUCTIVE FLOOR SPACE ——— $2.3035

TOOL AND GAGE CRIB COST

EQUIPMENT	INVESTMENT	DEPRECIATION AND INTEREST
CAGE, SHELVES, TOOL CHECKS, AND BINS	$200.00	$ 40.00
TOOL GRINDER	775.00	155.00
MISCELLANEOUS	200.00	100.00
TOTAL INVESTMENT	1175.00	
INTEREST ON INVESTMENT		70.50
TOTAL YEARLY TOOL AND GAGE CRIB COST		365.50
PLUS 10% FOR CONTINGENCIES		36.55
TOTAL		402.05

TOTAL OCCUPIED PRODUCTIVE FLOOR SPACE OF PLANT - 2160 SQ. FT.

J = TOOL AND GAGE CRIB COST PER SQUARE FOOT OF PRODUCTIVE FLOOR SPACE — $.018613

INDIRECT MATERIAL COST

MATERIAL AND EQUIPMENT	DEPRECIATION AND INTEREST
STANDARD HAND TOOLS AND GAGES	$ 879.45
OILS AND CUTTING COMPOUNDS	360.00
LUMBER FOR CRATES	35,700.00
TOTAL	36,939.45
PLUS 4% INTEREST	1,477.57
TOTAL INDIRECT MATERIAL COST FOR YEAR	38,417.02
PLUS 10% FOR CONTINGENCIES	3,841.70
TOTAL	42,250.72

TOTAL FLOOR SPACE OCCUPIED BY PRODUCTIVE MACHINES — 2160 SQ. FT

K = INDIRECT MATERIAL COST PER SQUARE FOOT OF PRODUCTIVE FLOOR SPACE — $19.5605

MACHINE HOUR RATE

A — COST OF MACHINE PLUS EQUIPMENT AND FREIGHT AND HANDLING
B — SCRAP VALUE OF MACHINE — 10% OF A
C — TIME IN WHICH MACHINE MUST BE WRITTEN OFF
D — TOTAL FLOOR SPACE CHARGEABLE TO MACHINE
E — HOURS MACHINE IS USE PER YEAR
HP — HORSEPOWER REQUIRED BY MACHINE
M — DEPRECIATION ON MACHINE PER YEAR — $\frac{A-B}{C}$
N — INTEREST ON A — 6%
P — TAXES — 2%
Q — INSURANCE — 1½%
R — MAINTENANCE — 1%
S — POWER COST PER YEAR — 0.746 HP. X 0.039 E

MACHINE HOUR RATE = $\frac{.0405A + E(.029HP + .759) + 28.944D}{E}$

Fig. 35. Determination of Machine Hour Rate.

indirect machining cost for that part.

A word of explanation as to the determination of our machine hour rates is necessary. The machine hour rate for a given machine will be

$$\text{M.H.R.} = \frac{A(M+N+P+Q+R)+S+EG+DF+DH+DJ+DK}{E}.$$

But M+N+P+Q+R (see lower right hand corner of Fig. 35) can be combined into 40.5 per cent. in the case of our plant. Item S, the power cost per year for a given machine was determined as follows:

$$S = 0.746 \text{ HP.} \times 0.039E,$$

where HP. is the horsepower required, E the number of hours the machine runs per year, 0.746 the number of kilowatts in one horsepower, and $0.039 the cost of one kilowatt hour of power. The formula can be reduced to

$$S = 0.029\text{HP.} \times E.$$

Substituting these values in our machine hour rate formula and factoring, we arrive at

$$\text{M.H.R.} = \frac{.405A+E(.029\text{HP.}+G)+D(F+H+J+K)}{E}.$$

Substituting the numerical values which in our plant are constant, we have

$$\text{M.H.R.} = \frac{.405A+E(.029\text{HP.}+.759)+D(6.8939+2.3035+.18612+19.5605)}{E}.$$

Combining terms, our final simplified formula for machine hour rate becomes

$$\text{M.H.R.} = \frac{.405A+E(.029\text{HP.}+.759)+28.944D}{E}.$$

The tool and fixture cost per piece was found by dividing the total yearly cost of tools, standard and special, and fixtures for the given piece by 300,000, the year's production.

The assembling cost consists of four items; labor, indirect machining, tool and fixture, and standard parts, cost. Determining these costs involved exactly the same procedures described above. In finding the indirect machining cost, the machine hour rate for the power driven conveyor was used.

Fig. 34, already given, shows how these various cost items were tabulated and summed up to give the total factory cost of one of our drill presses.

It will have been noted that we computed our indirect machining costs on the basis of the actual cutting time for the various operations instead of the actual running time. The sum of all the cutting times for the operations a machine performs gave us the quantity E in our machine hour rate formula. Thus a correct allocation of expenses was attained.

This practice of using the actual cutting time of the machines also served the purpose of giving us a measure of our tool engineering efficiency. We adopted the following criterion of tool engineering efficiency. The efficiency of a tool engineer in tooling up a given machine for a given operation is expressed by the ratio

$$\text{Tooling Efficiency} = \frac{\text{Cutting time}}{\text{Total machine running time}}.$$

Tool engineering of 100 per cent efficiency would succeed in achieving a ratio of 1.00; that is, every moment the machine was running it would be actually cutting metal, no time being wasted in waiting for loading, unloading, and adjustments by the operator.

A measure of the efficiency of our project as a whole would be the ratio

$$\text{Plant Efficiency} = \frac{\text{Total cutting times of all machines}}{\text{Total running times of all machines}}$$

for a given period. It was on this basis that we were graded in our work at our school. The grade we as a class were given for our work on this project was 73.1 per cent. Therefore, this paper is a specimen of 73.1 per cent efficient tool engineering.

EDITOR'S NOTE

What grade would you, as a practicing tool engineer receive on your latest tool engineering project? Is the efficiency of your plant better than 73.1 per cent?

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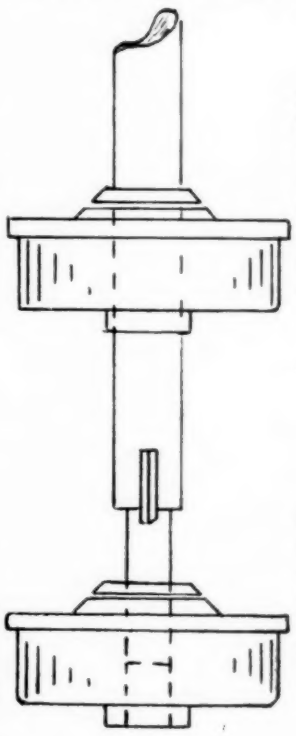

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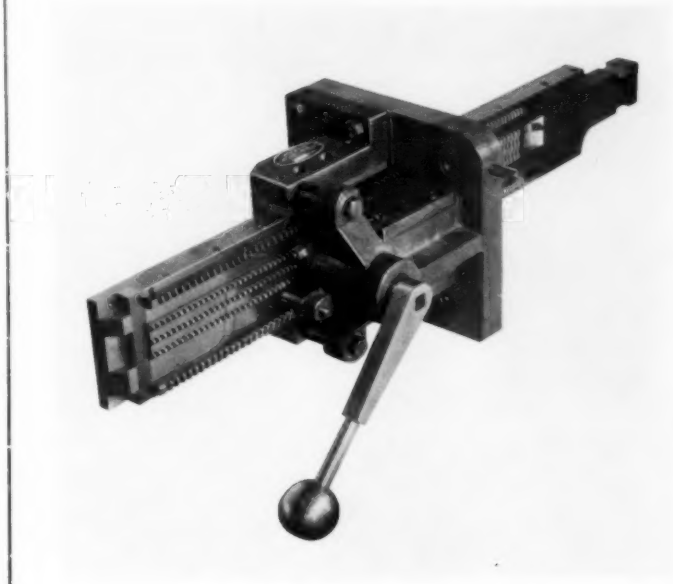

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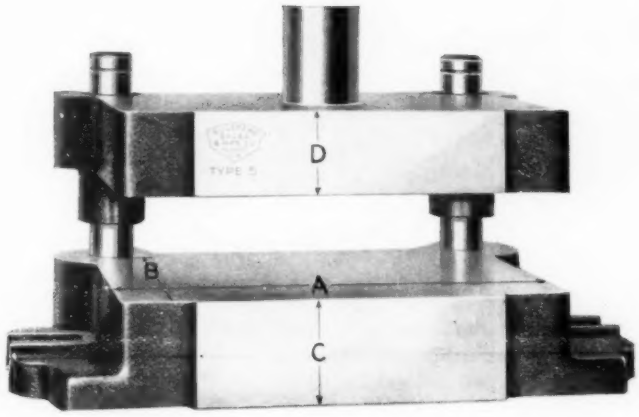

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